(19) Europäisches Patentamt
European Patent Office
Office européen des brevets

(11) Publication number: 0 670 654 A1

(12) EUROPEAN PATENT APPLICATION

(21) Application number: 95300986.7

(51) Int. Cl.6: H04N 1/40

(22) Date of filing: 16.02.95

(30) Priority: 02.03.94 US 205672

(43) Date of publication of application:
06.09.95 Bulletin 95/36

(84) Designated Contracting States:
DE FR GB

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(54) Multiple tone image generation.

(57) An N-tone image (102) is generated from a grey scale image (106) with a number of multi-level dither matrices (122). Both images have many pixels, with each pixel in the grey scale image having a grey level that is within a maximum and a minimum levels, and with each pixel in the N-tone image having a level that is one of N levels with N bigger than two. The method includes the step of determining (275,277) the level of each pixel in the N-tone image based on the levels of its corresponding pixel in the grey scale image, and an original dither matrix (250), the separations between adjacent levels in the N levels being non-uniform. In one embodiment a plurality of dither matrices (122) are used, which are generated by scaling the original dither matrix (250) according to the levels in each of the N groups (206,208) of grey levels. After the determination process, every pixel in the N-tone image is modelled (279) to represent its level. Based on the modelling, the N-tone image is printed (281).

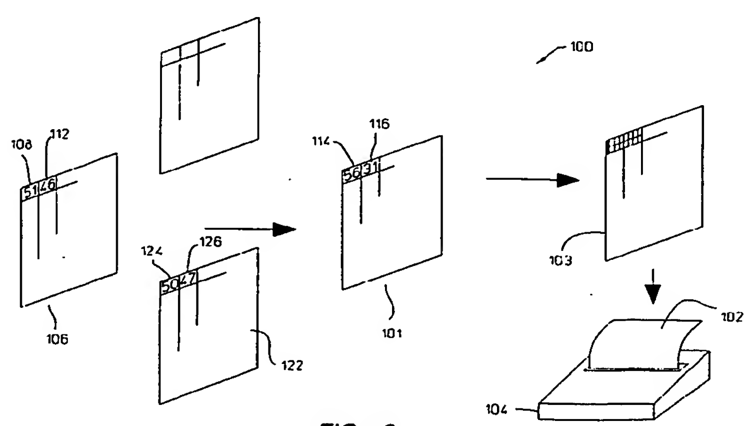


FIG. 2

EP 0 670 654 A1

The present invention relates generally to printing an image and more particularly to printing an image with N-tones. Other aspects of the subject matter disclosed herein are disclosed in our co-pending European patent application no. (RJ/N2969) filed the same day as this application.

Numerous methods are available to print a halftone image from a grey scale image. The methods usually involve establishing the approximate grey level of each pixel of the grey scale image, and then, based on some representation schemes, printing dots to represent the grey scale image.

One form of representation scheme depends on a dither matrix, which has the same number of pixels as the grey scale image. Each pixel in the matrix has a level, which is compared to the level of its corresponding pixel in the grey scale image to produce the level of a pixel in the halftone image. A general discussion of a dither matrix to render an image can be found in "Digital Halftoning," by R. Ulichney (1987). Another form of representation scheme depends on the error diffusion technique, with a general discussion found in "An Adaptive Algorithm for Spatial Greyscale," written by Floyd and Steinberg, and published in the Proc. SID, Volume 17, pages 75-77, 1976.

One type of dither matrix is known as a Bayer matrix. Figure 1 shows a prior art grey ramp at 300 dots per inch with 256 levels, printed using a Bayer matrix with 8 by 8 pixels. More than 50% of the grey levels in the ramp are indistinguishably black. This reduces the number of grey levels to print an image. Also, many transitions between distinguishable grey levels are not smooth, causing conspicuous discontinuities in a figure generated by the Bayer matrix.

The present invention seeks to provide improved N-tone image generation.

According to an aspect of the present invention, there is provided a method of generating an N-tone image as specified in claim 1.

The invention also extends to apparatus suitable for implementing such a method.

It is possible with some embodiments to generate from a grey scale image an N-tone image with more distinguishable grey levels and better transitions between adjacent levels, in a relatively inexpensive manner. The preferred method is based on generating a N-tone image, instead of a halftone image.

In one preferred embodiment, the level of each pixel in the N-tone image is determined based on the levels of its corresponding pixel in the grey scale image and based on an original dither matrix; the separations between adjacent levels in the N levels are non-uniform. After the determination process, every pixel in the N-tone image may be modelled to represent its level. Based on the modelling, the N-tone image can be printed.

One preferred method to model each pixel is to replace every pixel in the N-tone image by many contiguous sub-pixels. The level of each pixel can be represented by the intensity for each of its corresponding sub-pixels so that different combination of intensities of the sub-pixels produce different levels for that pixel. Based on the above method, the N-tone image printed can have smoother transitions between adjacent grey levels and more distinguishable grey levels in its grey ramp.

An embodiment of the present invention is described below, by way of example only, with reference to the accompanying drawings, in which:

Figure 1 shows a prior art grey ramp printed using a Bayer matrix.

Figure 2 shows a representation of a first preferred embodiment.

Figure 3 shows a preferred table of groups of grey levels to generate a N-tone image for the first preferred embodiment.

Figure 4 shows one preferred way to form a multi-level dither matrix.

Figure 5 shows one multi-level dither matrix formed by the method described in Figure 4.

Figure 6 shows one preferred way to form the N-tone image of the first preferred embodiment.

Figure 7 shows one preferred way to generate sub-pixels and segments in the first preferred embodiment.

Figure 8 shows the formation of sub-pixels in the first preferred embodiment.

Figure 9 shows one preferred sets of segments for four sub-pixels.

Figure 10 shows the 16 levels printed using the different segments in Figure 9.

Figure 11 shows the relationship between the grey levels and the density of each level in the N-tone image of the first preferred embodiment.

Figure 12 shows a picture printed by the first preferred embodiment.

Figure 13 shows an example for the second preferred embodiment, with 16 contiguous sub-pixels to form one pixel.

Figure 14 shows the turn-on sequence of the sub-pixels to generate 13 different levels for the second preferred embodiment.

Figure 15 shows one table of groups of grey levels for the second preferred embodiment.

Figure 16 shows the grey ramp generated based on the second preferred embodiment.

Figure 17 shows a part of a fourth preferred embodiment.

Figure 18 shows a preferred way for the fourth preferred embodiment.

Figure 19 shows graphically one preferred way to form the special dither matrix in the fourth preferred embodiment.

Figure 20 shows a set of preferred steps to form the special matrix in Figure 19.

The following description is directed solely to a method of generating an N-tone images. However, the description is also intended to teach how to provide a system for generating such an image which includes suitable system means or units for effecting the various method steps. No detailed description of the system is given as its structure will be immediately apparent to the skilled person from a reading of this description, whether the system is designed by means of software or hardware or any combination of the two.

Figure 2 shows a representation of a first preferred embodiment 100 which prints a N-tone image 102 by a printer, a plotter or other imprinting device 104 from a grey scale image 106. The N-tone image 102 has two intermediate forms, the first intermediate N-tone image 101 and the second intermediate N-tone image 103. The images have many pixels; for example, the grey scale image 106 has pixels 108 and 112; and the first intermediate N-tone image 101 has pixels 114 and 116.

Each pixel in the grey scale image has a level that is within a maximum and a minimum level. For example, the maximum level is 255 and the minimum level is 0; each level represents one grey level of the grey scale image 106.

The first intermediate N-tone image 101 has N levels, with N preferably greater than 2. The level of each pixel in the first intermediate N-tone image 101 is from one of the N levels. The N levels are selected from the grey levels in the grey scale image 102 by dividing the grey levels into N groups. Each group of grey levels has a group maximum level, which is the maximum level in the group and is one of the N levels. The separations between adjacent levels in the N levels are non-uniform. The method to set the non-uniformity will be described later in the specification.

Figure 3 shows an example of a preferred table of groups of grey levels to generate a N-tone image with 16 levels. The sixteenth group 202 covers the range of grey levels between 255 to 253 with its group maximum level being 255. Every group is represented by its group maximum level. The entire 16 groups give rise to 16 group maximum levels, which represent the 16 levels of the N-tone image.

The first preferred embodiment includes a number of multi-level dither matrices 118, such as the multi-level dither matrix 122. Each multi-level dither matrix has many pixels, such as the matrix 122 has pixels 124 and 126.

The multi-level dither matrices are formed through the groups of levels shown in Figure 3 and an original dither matrix. Figure 4 shows one preferred way 260 to form a multi-level dither matrix 122 as the one shown in Figure 5. First, N groups of levels are formed, 262, as in Figure 3. Then the matrices are formed through scaling 264 the original dither matrix according to the groups of levels. The original dither matrix 250 may be a Bayer matrix or other types of dither matrix with levels ranging such as from 1 to 255; the matrix is the type that has been used extensively to render an image and will not be further described in this application. The multi-level dither matrix 122 shown in Figure 5 corresponds to the fourth group 206 of grey levels shown in Figure 3, which covers the grey levels from 56 to 31. To form the multi-level dither matrix 122, the levels in the original dither matrix (1 to 255) are scaled according to the levels in the group 206, with grey levels ranging from 56 to 31; for example, the level 167 in the second pixel of the original dither matrix becomes the level 47 in the second pixel of the multi-level dither matrix using the following direct scaling calculation, with fractions rounded off:

$$(((56-31)/(255-1))*167 + 31).$$

Similarly, the level 40 in the pixel 257 of the original dither matrix becomes 35 in the pixel 259 of the multi-level dither matrix. Based on the above method, the multi-level dither matrix 122 is formed. Using the original dither matrix and the 16 groups of grey levels shown in Figure 3, sixteen multi-level dither matrices are generated by the direct scaling calculations. Figure 6 shows a set of preferred steps to form the N-tone image, based on the multi-level dither matrices.

To generate the first intermediate N-tone image 101, every pixel in the grey scale image 106 is compared to and thresholded by a pixel in one of the multi-level dither matrices. For example, the first pixel 108 in the grey scale image 106 has the grey level 51. This grey level falls within the fourth group of grey levels shown in Figure 3. The multi-level dither matrix 122, generated by the fourth group of grey level, is selected, 275. The first pixel of the grey scale image is then compared, 277, to the first pixel of the multi-level dither matrix 122. In the comparison process, first, one decides if the level of the pixel in the grey scale image is larger than or equal to the level in the corresponding pixel of the multi-level dither matrix; if it is, the group maximum level of the corresponding group generating the multi-level dither matrix is chosen for the first intermediate N-tone image; however, if the level of the pixel in the grey scale image is smaller, the group maximum level of the subsequent group

is chosen for the first intermediate N-tone image. In the present example, with 51 bigger than 50, the group maximum level, 56, is chosen to be the level of the first pixel in the first intermediate N-tone image. For the second pixel, with 46 less than 47, the group maximum level of the subsequent group, 31, is chosen to be the level in the N-tone image. From the levels in the grey scale image and the multi-level dither matrices, the pixel-to-pixel comparison method, as described above, generates the first intermediate N-tone image 101.

The second intermediate N-tone image 103 is generated by two steps. First, each pixel in the first intermediate N-tone image 101 is represented or modelled, 279, by a number of contiguous sub-pixels, and then each sub-pixel is represented or modelled by a number of segments.

While not wishing to be bounded by theory, it is believed that some of the advantageous results of the method described above are obtained through understanding the functionality of relatively low-cost printers. To generate an image with substantially imperceptible dots, every pixel is printed by, for example, a laser printer with a resolution of at least 600 pixels or dots-per-inch. The characteristics of each pixel is preferably controlled through a pulse with a pulse width. The pulse width can be sub-divided into a number of segments. Each segment can be at a high or a low intensity; at a high intensity means that the segment is dark or that the segment is turned on with the pulse width extending into the segment; and at a low intensity means the segment is light or the segment is turned off with the pulse width not extending into the segment. For a typical present-day 600 dots-per-inch laser printer, if the pulse is divided into eight segments, it is preferable to have more than one segment at a high intensity to generate a reproducible output. In other words, every segment at a high intensity preferably should have a neighboring segment also at a high intensity. Based on this representation, different levels of the image require different pulse widths or require selecting different number of segments. In order to generate more levels for the output image, every pixel in the N-tone image is represented or modelled by a number of pixels; the number of pixels is designated as sub-pixels. In one preferred embodiment, by combining four sub-pixels to generate different levels for each pixel, one gets N-tone images with a 300 dots-per-inch resolution; the N-tone images generated have substantially imperceptible dots for the unaided eyes of an ordinary person, with 20/20 vision, under normal condition. The above theory also applies to other relatively low-cost printers, such as ink-jet printers, by varying the intensity of each printed dot in a way similar to varying the pulse width in each pixel of a laser printer. Then, using the above methods it is possible to generate images with substantially imperceptible dots.

One example of using sub-pixels and segments is illustrated in Figures 8 and 9, with a set of preferred steps shown in Figure 7. The example is based on a 600 dots-per-inch laser printer. Figure 8 shows each pixel in the first intermediate N-tone image 101 being replaced, 283, by four contiguous sub-pixels; for example, the pixel 114 is replaced by the sub-pixels 302, 304, 306 and 308. Figure 9 shows the four sub-pixels, with each sub-pixel replaced, 285, by eight segments. There is a number within each segment; for example, the segment 310 has a number of 15, and the segment 312 has a number of 1. The number inside the segment represents the level of the pixel when the segment is turned on or is at the high intensity. For example, for the level 15, the pulse width extends across three segments, the segment 310, 314 and 316; for the level 1, the darkest level, the pulse width extends across all the segments; and for the level 16, no segment is turned on or all segments are at the low intensity. Thus, the level of each pixel is represented, 287, by the segments and the sub-pixels.

The sixteen levels have perceptibly different levels of grey. One preferred way to decide which segment to be turned on for which level is based on one's visual perception. In the embodiment shown in Figure 9 with 32 segments, the segments are turned on one after the other, with the level created measured by a densitometer, which measures the density of a level. Theoretically, there could be 33 levels from the 32 segments, but many levels are visually indistinguishable. Those indistinguishable levels are grouped as one level, for example the numerous segments grouped together for level 1 and level 2. In this embodiment, sixteen distinguishable levels are selected. Another observation in the preferred embodiment, using a 600 sub-pixels-per-inch laser printer, is that the lightest level 15 preferably needs more than 1 segment. The effect of a segment turned on by itself without any neighboring segments being turned on may not be very reproducible. Thus, the lightest level preferably needs more than one segment to be turned on. However, once there are segments turned on, subsequent levels may only need one additional segment to be perceptibly different. For example, the level 14 only has one more segment turned on, as compared to the level 15. In this embodiment, the number of segments between levels is not uniform; for example, the difference between levels 16 and 15 is 3 segments, and the difference between levels 15 and 14 is 1 segment only.

Another preferred way to decide which segment to be turned on for which level is to retain the

33 levels for the 32 segments. A number of levels may not be visually distinguishable, and one needs 6 bits to designate all the levels. If the number of bits is of concern, one may remove one level, and then only 5 bits would be needed to designate the 32 levels.

The above example is based on a 600 sub-pixels or dots-per-inch laser printer. Laser printers with higher resolution can be used. The number of sub-pixels for each pixel does not have to be 4. The number of segments for each sub-pixel does not have to be 8. By experimenting with the number of segments, the number of sub-pixels and the dot size, one, based on the teachings in the present disclosure, can generate images with substantially imperceptible dots, with a different resolution, a different number of sub-pixels and a different number of segments.

Figure 10 shows the 16 levels printed out using the different pulse widths or segments shown in Figure 9. For example, the fourth square block, 325, is the fourth level. As shown in Figure 9, all the segments having number 4 or higher in it will be turned on, which means that pulses are turned on for three sub-pixels, 304, 304 and 306; in other words, 24 of the 32 segments are turned on.

The 16 levels shown in Figure 10 are measured by the densitometer. The density of each level of the N-tone image is related back to the grey levels of the grey scale image. In one preferred embodiment, the relationship is assumed to be linear. Figure 11 shows the relationship between the grey levels and the density of each level of the N-tone image. Each level in Figure 10 is mapped to a group or a range of grey levels. For example, the fourth level approximately has a grey level of 56, and the third level has 31; so the fourth group of levels covers the grey levels from 56 to 31. This is one preferred method to determine all the groups of grey levels in Figure 3.

From the second intermediate N-tone image 103, the N-tone image 102 is printed, 281, by the printer 104. In the present embodiment, one way to represent a segment being turned on is to use a value of 1, and a segment being turned off by a value of 0. The segments with 1 in them will be printed. Figure 12 shows a picture printed out by the first preferred embodiment. The image has 300 dots or pixels per inch. Each pixel is represented by 4 sub-pixels, and each sub-pixel by 8 segments. There are altogether 32 segments for each pixel. In this embodiment, each pixel only has 16 levels, which can be represented by 4 bits. Thus, with an increase of 4 bits for every pixel, for an ordinary person, the figure generated has substantially imperceptible dots. Any dots in the figure, such as those on the apple, are in the original grey scale image.

A second preferred embodiment is similar to the first except one does not have to vary the pulse width, or use different segments for each sub-pixel in the second intermediate dither matrix 103. The N-tone image is generated, for example, through an original Bayer matrix with 8 by 8 pixels.

In one example of the second embodiment, every pixel is represented or modelled by 16 contiguous sub-pixels, as shown in Figure 13. Figure 14 shows the turn-on sequence of the sub-pixels to generate 13 different levels. For example, if one prefers the fourth level, every sub-pixel labelled 4 or higher will be turned on, or will have a dot printed in it. This turn-on sequence is determined based on a classical screen or cluster dot at 45° model; such model should be obvious to those skilled in the art and will not be further described here. From the 13 levels, a densitometer generates 13 groups of levels according to a graph similar to Figure 11. Figure 15 shows the groups of levels found. Again, the separations between the groups of levels are not uniform.

From the 13 groups of levels in Figure 15, the original Bayer matrix forms 13 multi-level dither matrices. From the multi-level dither matrices, the first intermediate dither matrix 101 is generated. Based on the 13 levels as shown in Figure 14, the second intermediate N-tone image and the N-tone image are produced as in the first preferred embodiment.

Figure 16 shows the grey ramp with 256 grey levels generated based on second preferred embodiment with the multi-level Bayer matrices and the 13 levels. The pixels have a resolution of 75 dots-per-inch, with the sub-pixels at 300 dots-per-inch. As compared to the prior art grey ramp in Figure 1, there are significantly more distinguishable grey levels. Moreover, the transition between grey levels in Figure 16 are more smooth than those in Figure 1. These effects are more obvious to a viewer if the two figures are viewed side-by-side at a distance, such as 60 centimetres (2 feet away) from the viewer.

For a third preferred embodiment, its main difference from the first preferred embodiment is that the multi-level dither matrices are replaced by a multi-levelling error diffusion technique to generate the first intermediate N-tone image 101. In the normal error diffusion technique, the error from each pixel is compared to the middle grey scale level of the grey scale image, with the errors diffused to its surrounding pixels. Error diffusion techniques are well-known to those with ordinary skill in the art and will not be further described in the specification. For the preferred multi-level error diffusion technique, the level in each grey scale image pixel again maps to a corresponding group of grey levels, such as the one shown in Figure 3.

The level in each pixel of the grey scale image is compared to the middle level of its corresponding group of levels, and the error is again diffused to its corresponding pixels to generate the first intermediate N-tone image 101. For example, the first pixel 108 with a level of 51 is compared to the level 43 (the average of 56 and 31), and the error is diffused to its neighbors.

Figure 17 shows a portion of a fourth preferred embodiment 401, with a set of preferred steps shown in Figure 18. The difference between the first and the fourth embodiment is that the fourth embodiment reduces the number of steps in the first embodiment by collapsing many steps into one special dither matrix. In this embodiment, the level of each segment in a second intermediate N-tone image 404 is determined by a pixel-to-pixel comparison between the grey scale image 400 and the special dither matrix 402. Based on the comparisons, the level in each pixel of the N-tone image is determined, 375. Then, from the second intermediate N-tone image 404, the N-tone image is printed, 377, by the printer. In another embodiment, one preferably does not need to determine, 375, the level in each pixel. All the segments in the second intermediate N-tone image 404 are sent as a bit map to the printer, and the bit map is printed directly.

In one preferred embodiment, as shown in Figure 17, every pixel in the grey scale image 400 is subdivided into a group of contiguous segments to form a finer-resolution grey scale image 406. All the segments for each pixel may have the same grey level as its corresponding pixel in the grey scale image 400; for example, the first pixel 408 with a level of 206 is subdivided into thirty-two contiguous segments, such as 410, 412, 414 and 416; all the segments have the level of 206. For another embodiment, the finer-resolution grey scale image 406 actually has a finer resolution than the grey scale image 400; for example, thirty-two times higher in resolution. After the sub-division, each segment in the finer-resolution grey scale image is compared to its corresponding segment in the special dither matrix 402.

Figure 19 graphically shows one preferred way to form the special dither matrix 402, with a set of preferred steps shown in Figure 20. As an overview, many standard grey scale images, such as 460, 462 and 464, are first compared, 500, to the multi-level dither matrices, such as 118 and 122, to produce many intermediate output matrices, such as 450, 452 and 454. Then, every pixel in the intermediate output matrices is replaced by a group of contiguous sub-pixels as in the first preferred embodiment to form, 502, many output matrices, such as 470, 472 and 474. All the output matrices are added, 504, together to form the special dither matrix 402.

In more detail, every pixel in each standard grey scale image has the same grey level. For example, all the pixels in the standard grey scale image 460 has the grey level 0. The grey scale image may have 256 levels. In order to cover all the levels, there are preferably 256 standard grey scale images.

The multi-level dither matrices are generated as in the first preferred embodiment. For each standard grey scale image, its pixels are compared to one corresponding multi-level dither matrix to generate its intermediate output matrix. The comparison is similar to the comparison in the first preferred embodiment. For example, the standard grey scale image 462 has the level of 45 for all its pixels. Its corresponding multi-level dither matrix is 122, which covers the levels from 56 to 31. Thus, every pixel in the standard grey scale image 462 is compared to its corresponding pixel in the multi-level dither matrix 122 to generate the intermediate output matrix 452.

All the intermediate output matrices are transformed to their corresponding output matrices by replacing every pixel with a group of contiguous segments. This replacement process is similar to the replacement process in generating the second intermediate N-tone image from the first intermediate N-tone image in the first embodiment. For example, each pixel in the intermediate output matrices is replaced by 32 segments with their corresponding intensity to represent the level of each pixel; the segments that should be turned on have one in them, and those that should be turned off have zero. After the replacement, every intermediate output matrix becomes its corresponding output matrix. For example, the intermediate output matrix 452 becomes the output matrix 472 after the replacement process. All the output matrices are then added together by matrix addition to produce the special dither matrix 402.

A Bayer matrix may be used for the fourth preferred embodiment. The difference is that every pixel in the intermediate output matrix is not replaced by segments, but by sub-pixels only, as in the second preferred embodiment. A sub-pixel that should be turned on has one in it and the one that should be off has a zero in it.

It is therefore possible to generate visually pleasing N-tone images in a relatively inexpensive manner. The above-described embodiment can be modified for color images. For a color N-tone image, the methods are repeated at least two more times, each time for a different color to generate the color N-tone image. They can also be used for a display with the N-tone image shown on the display, instead of printed on a printer. In fact, the printing step described above includes displaying,

with the printer being a display.

The disclosures in United States patent application no. 08/205,672, from which this application claims priority, and in the abstract accompanying this application are incorporated herein by reference.

Claims

1. A method of generating a N-tone image (102) from a grey scale image (106), both images being formed from a plurality of pixels, each pixel in the grey scale image (106) having a grey level within maximum and minimum levels, and each pixel in the N-tone image (102) having one of N levels with N bigger than two, the method comprising the steps of determining (275, 277) the level of each pixel in the N-tone image based on the levels of its corresponding pixel in the grey scale image and based on an original dither matrix, the separations between adjacent levels in the N levels being non-uniform; modelling (279) the level of every pixel in the N-tone image; and printing (281) the N-tone image based on the modelled pixels.

2. A method as recited in Claim 1, wherein the determining step comprises selecting (275) for every pixel of the grey scale image a multi-level dither matrix from a plurality of multi-level dither matrices generated on the basis of the N levels and the original dither matrix; and comparing (277) the level of each pixel in the grey scale image and the level of the corresponding pixel in the selected multi-level dither matrix to determine the level of the corresponding pixel in the N-tone image.

3. A method as recited in Claim 2, wherein there are N multi-level dither matrices generated by the steps of dividing (262) the levels in the grey scale image into N groups based on the N levels of the N-tone image; and scaling (264) the original dither matrix by the levels in each group to generate the N multi-level dither matrices.

4. A method as recited in Claim 1, 2 or 3, wherein there are visually perceptible changes in intensity between adjacent levels in the N levels of the N-tone image.

5. A method as recited in any preceding Claim, wherein the N-tone image is in black-and-white.

6. A method as recited in any one of Claims 1 to 3, wherein the N-tone image is in color; and the method further comprises the step of repeating the method more than once, each time for a different color to generate the color N-tone image.

7. A method as recited in any preceding Claim, wherein the step of modelling (279) comprises modelling with sub-pixels to generate N levels; and the steps of determining and modelling depend on a special dither matrix (402) and a plurality of standard matrices (460, 462).

8. A method as recited in Claim 7, wherein the special dither matrix is generated by operating (500) each standard matrix by one of a plurality of multi-level dither matrices to generate its corresponding intermediate output matrix, the multi-level dither matrices being formed from the N levels and the original dither matrix; producing (502) a plurality of output matrices through modelling every pixel in the intermediate output matrices by the plurality of contiguous sub-pixels; and adding (504) the output matrices.

9. A method as recited in Claim 8, wherein the pixels in each standard matrix have the same grey level, and the levels from all the standard matrices cover all the levels in the grey scale image; and the multi-level dither matrices are generated by dividing (262) the levels in the grey scale image into N groups based on the N levels of the N-tone image, and scaling (264) the original dither matrix by the levels in each group to generate the N multi-level dither matrices.

10. A method as recited in Claim 1, wherein the step of modelling includes replacing (283) every pixel in the N-tone image by a plurality of sub-pixels, each sub-pixel having an intensity; and representing (287) every level of each pixel by the intensity of its corresponding sub-pixels.

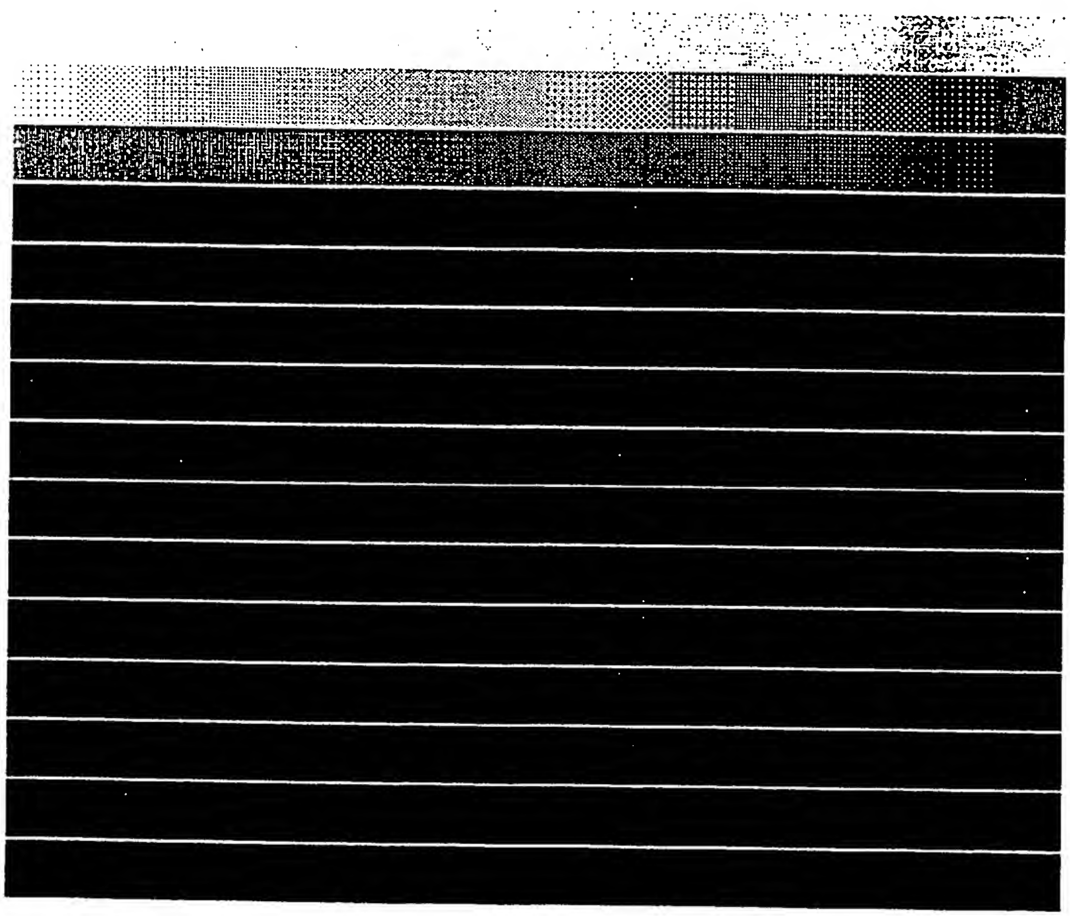


FIG. 1 (Prior Art)

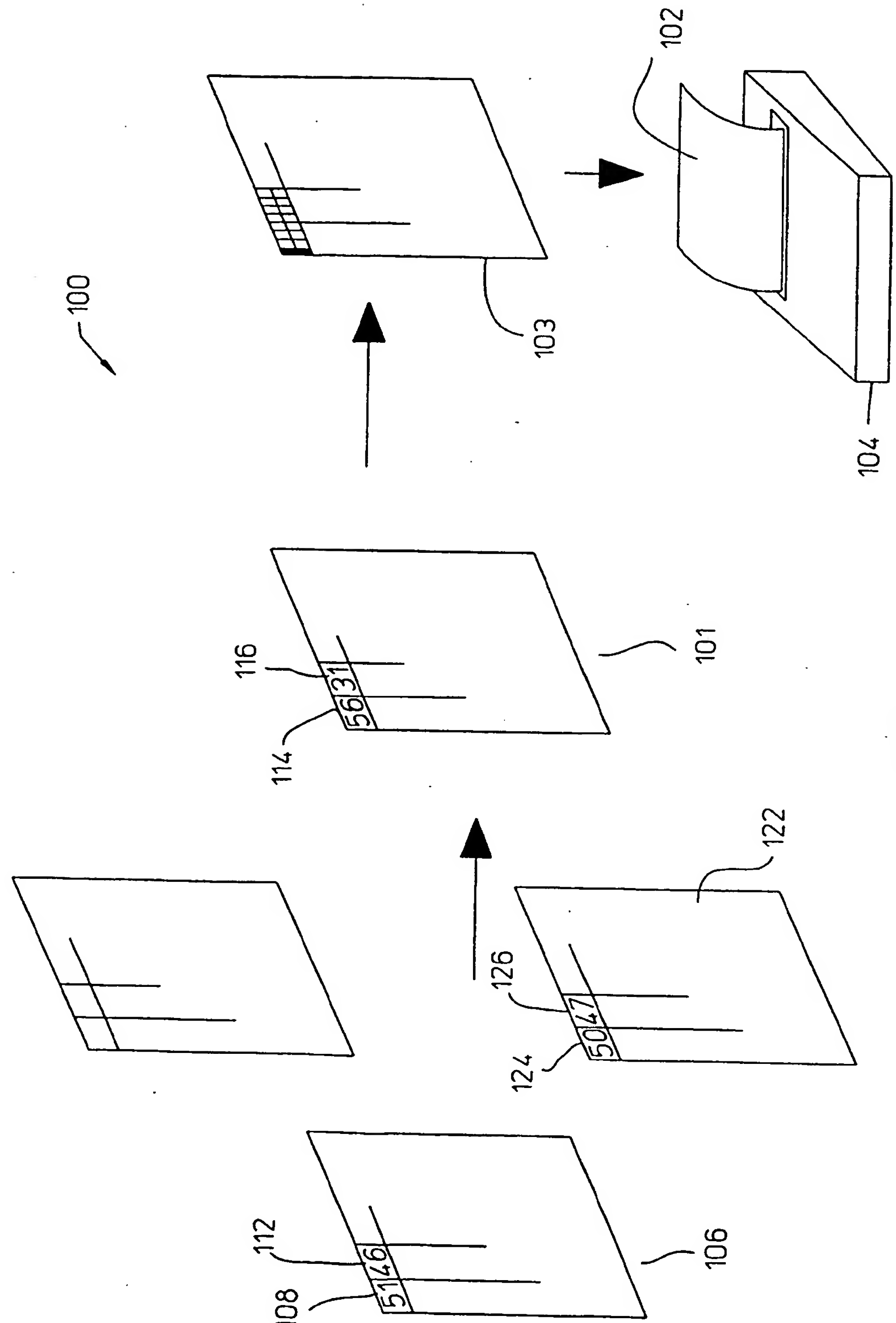

100
102
103
104
116
114
56
31
101
122
126
124
50
47
112
108
51
46
106

FIG. 2

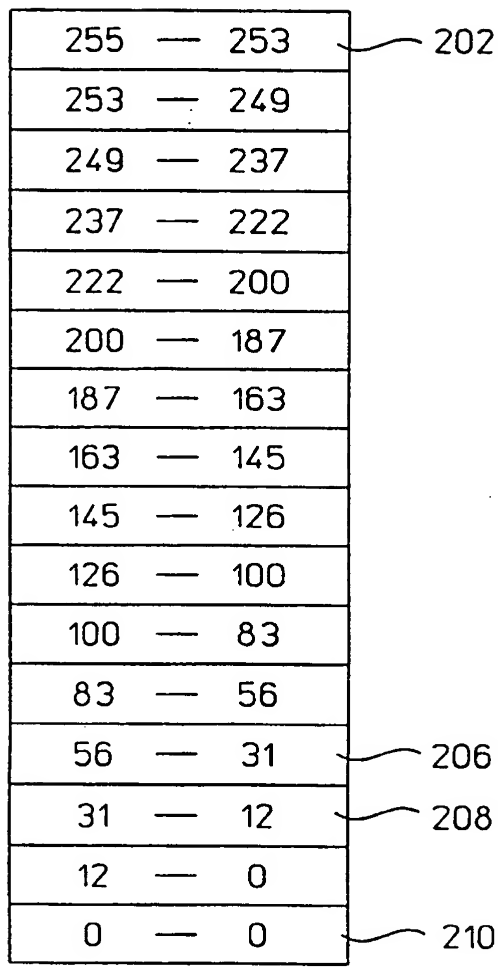

255 — 253
253 — 249
249 — 237
237 — 222
222 — 200
200 — 187
187 — 163
163 — 145
145 — 126
126 — 100
100 — 83
83 — 56
56 — 31
31 — 12
12 — 0
0 — 0
202
206
208
210

FIG. 3

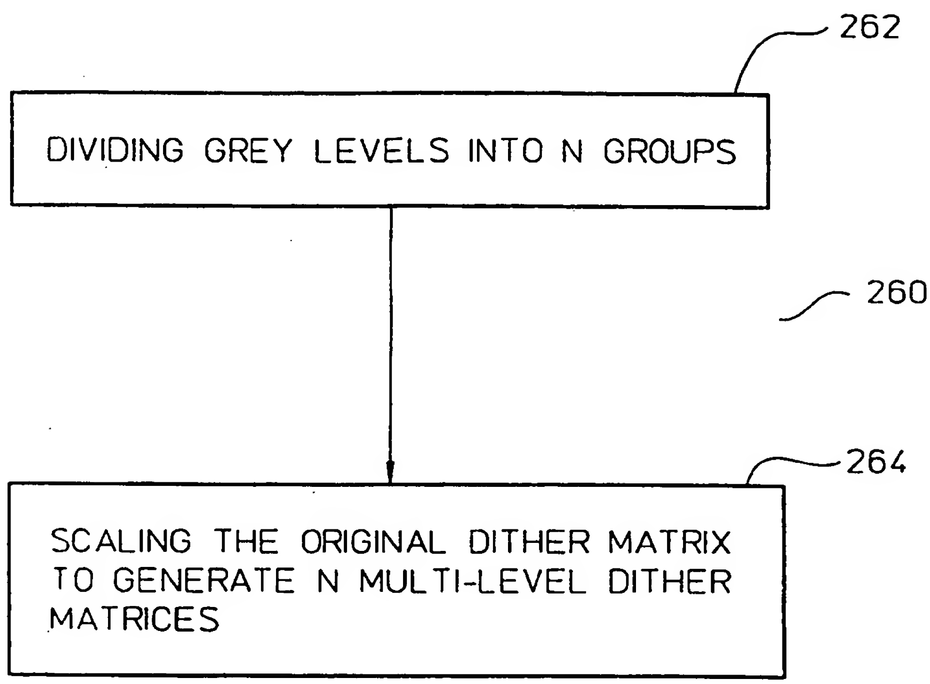

262
DIVIDING GREY LEVELS INTO N GROUPS
260
264
SCALING THE ORIGINAL DITHER MATRIX TO GENERATE N MULTI-LEVEL DITHER MATRICES

FIG. 4

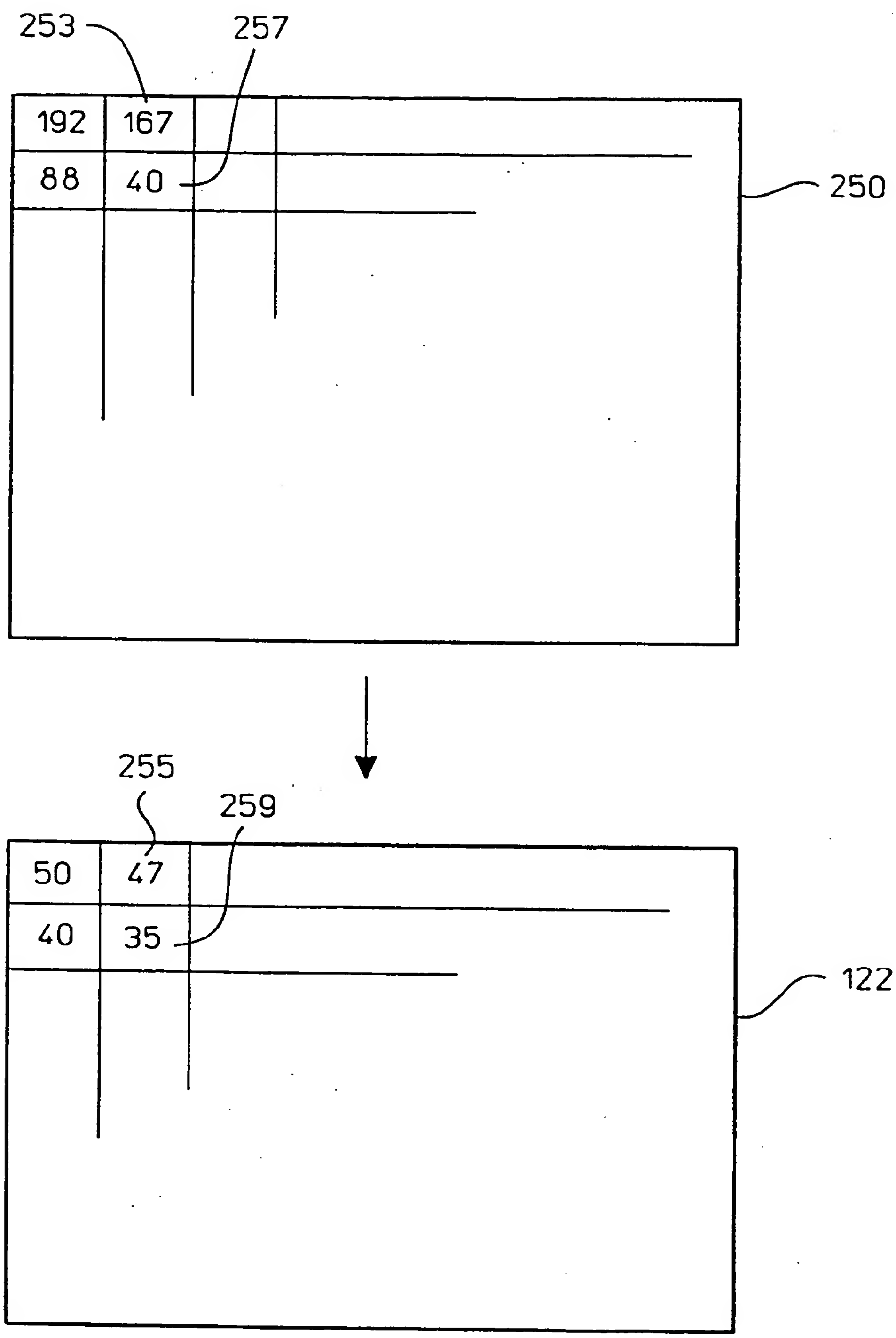


FIG. 5

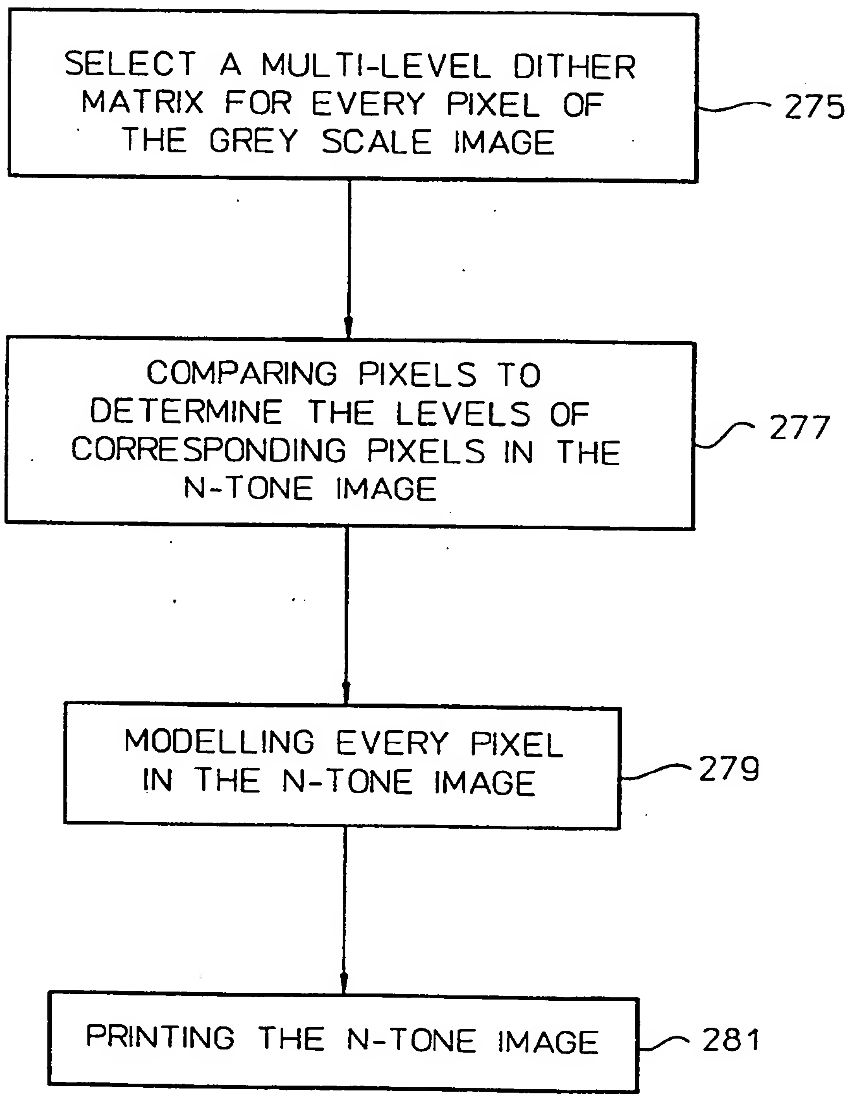

SELECT A MULTI-LEVEL DITHER MATRIX FOR EVERY PIXEL OF THE GREY SCALE IMAGE
275
COMPARING PIXELS TO DETERMINE THE LEVELS OF CORRESPONDING PIXELS IN THE N-TONE IMAGE
277
MODELLING EVERY PIXEL IN THE N-TONE IMAGE
279
PRINTING THE N-TONE IMAGE
281

FIG. 6

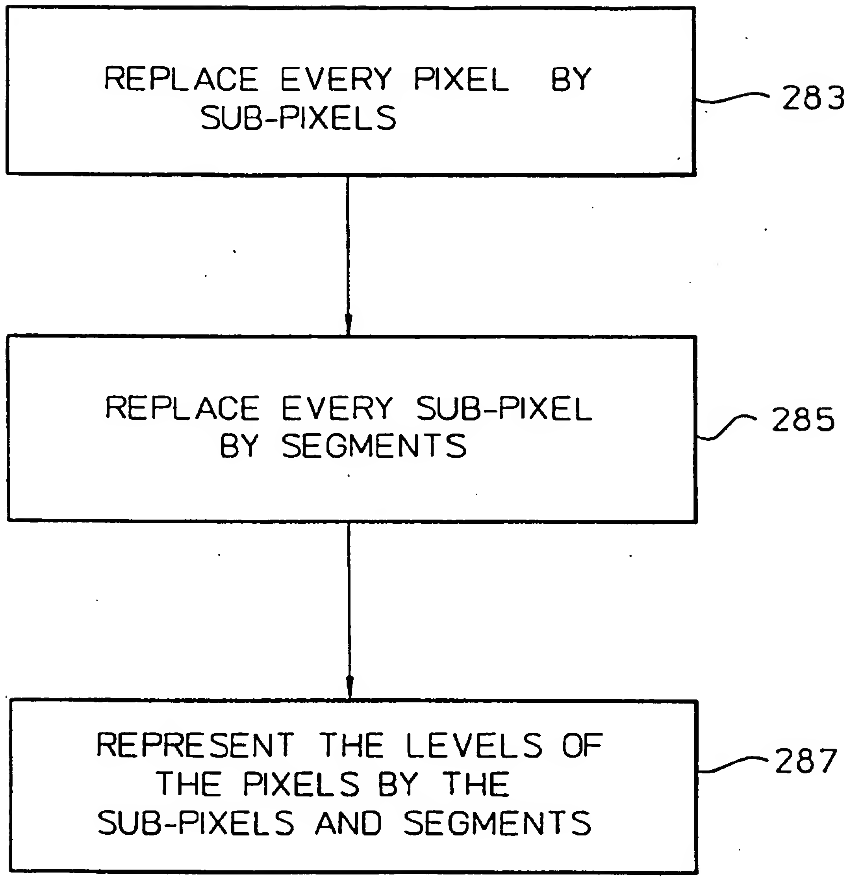

REPLACE EVERY PIXEL BY SUB-PIXELS
283
REPLACE EVERY SUB-PIXEL BY SEGMENTS
285
REPRESENT THE LEVELS OF THE PIXELS BY THE SUB-PIXELS AND SEGMENTS
287

FIG. 7

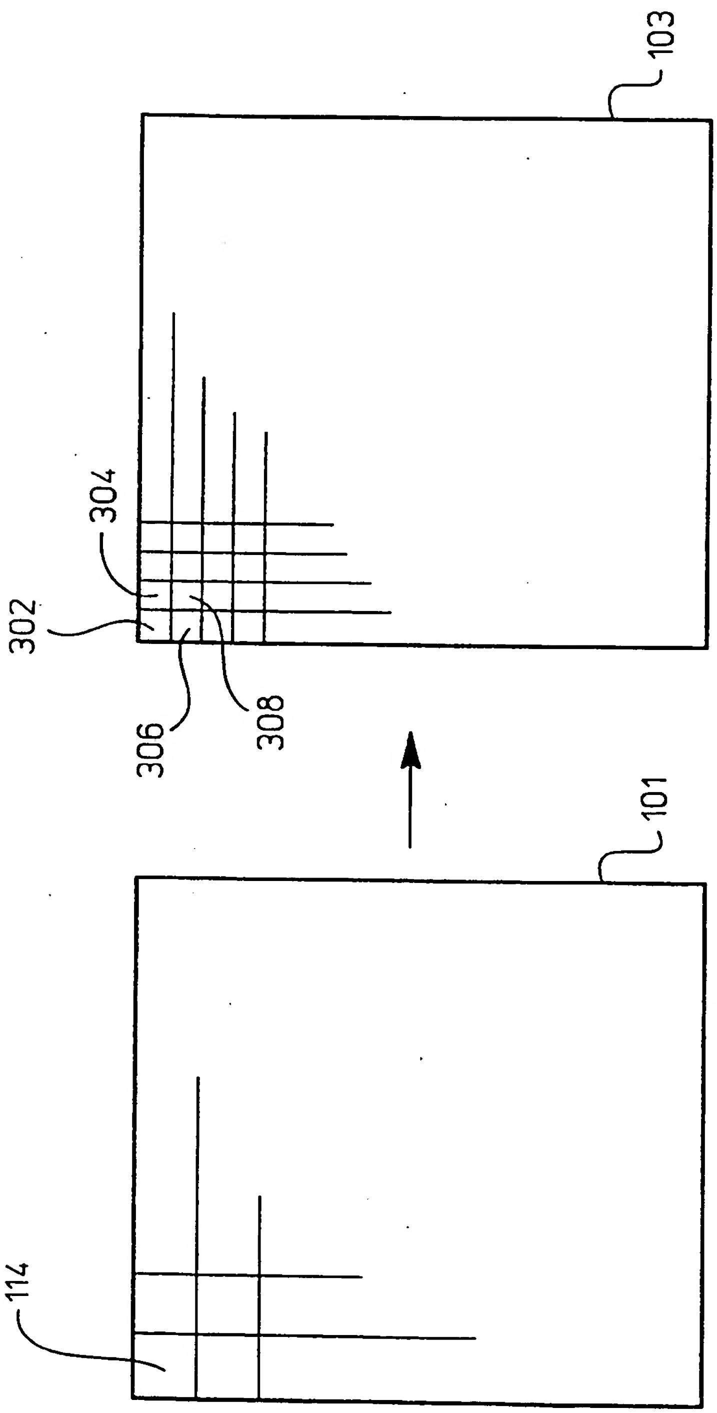
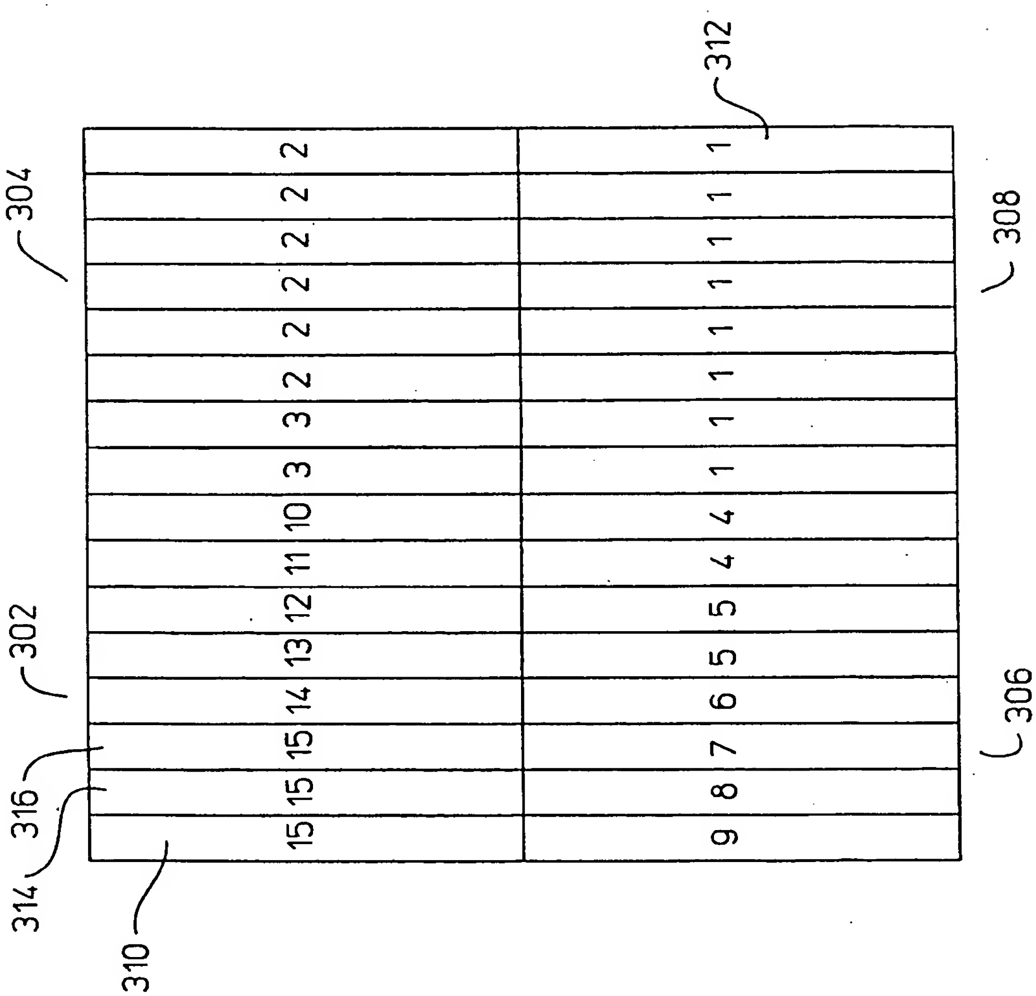


FIG. 8

FIG. 9



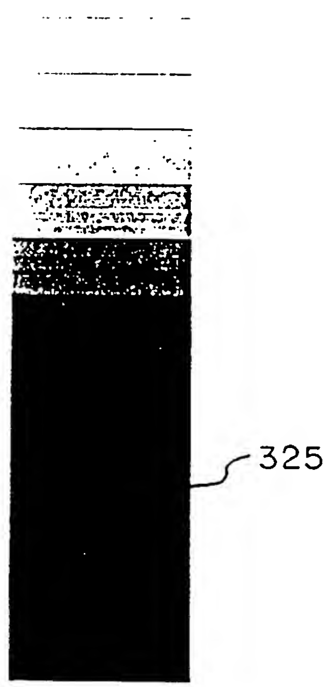


FIG. 10

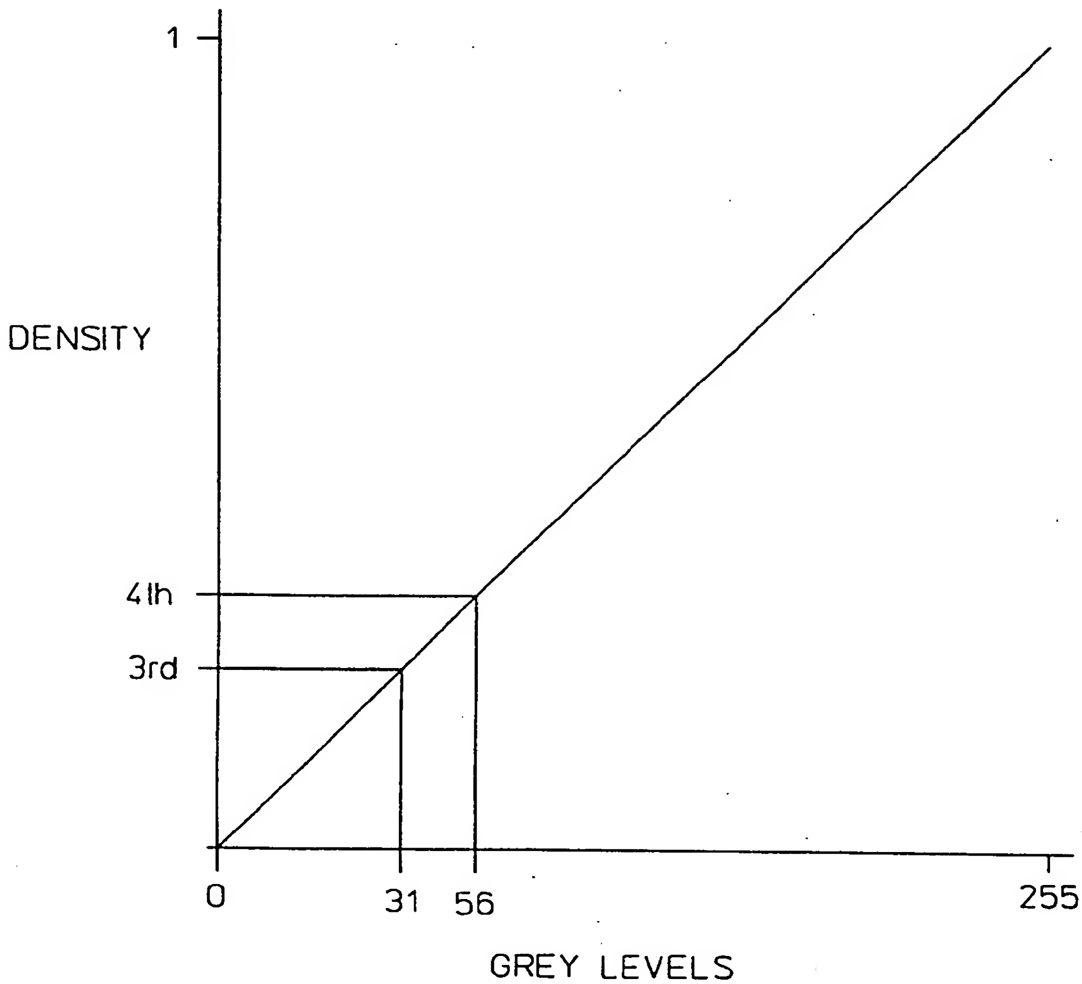


FIG. 11

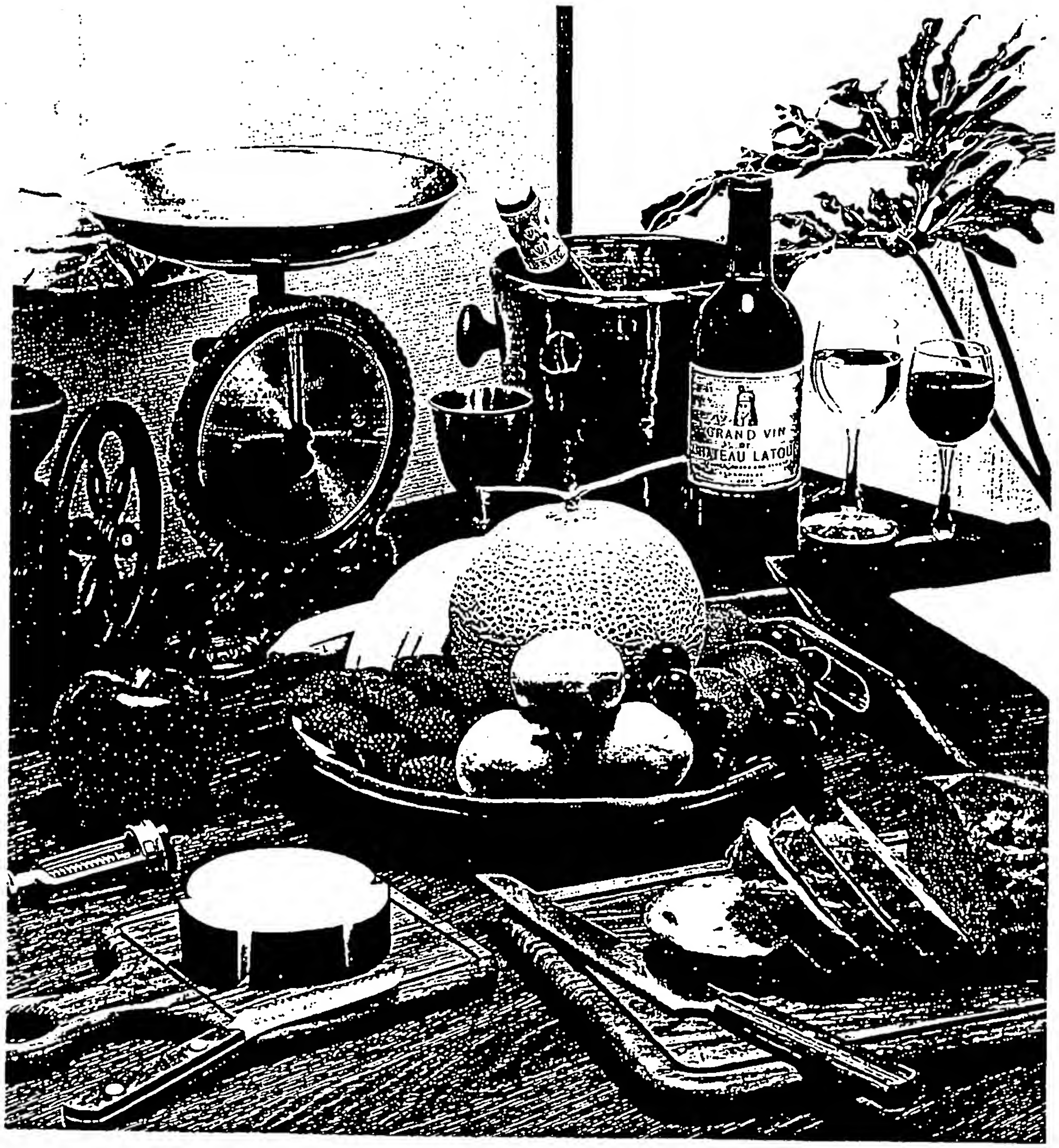


FIG. 12

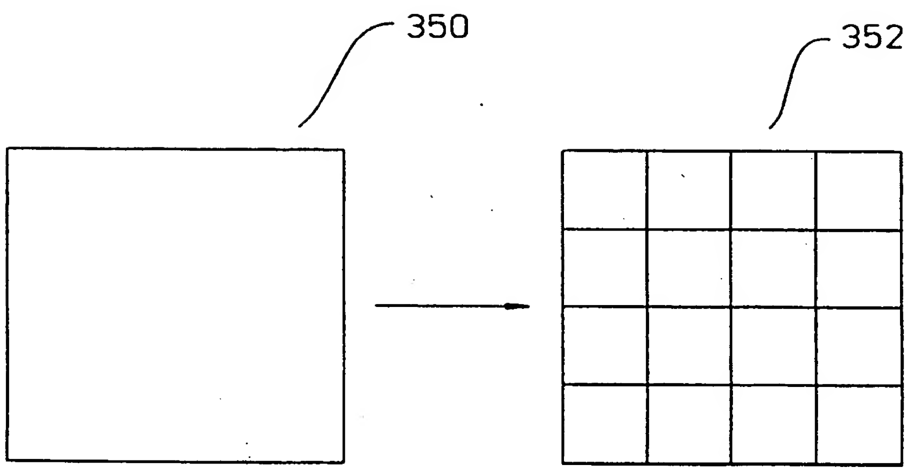


FIG. 13

12	8	1	3
10	6	1	1
4	2	11	7
1	1	9	5

FIG. 14

255	—	243
243	—	213
213	—	185
185	—	157
157	—	135
135	—	116
116	—	107
107	—	77
77	—	65
65	—	30
30	—	22
22	—	0
0	—	0

FIG. 15

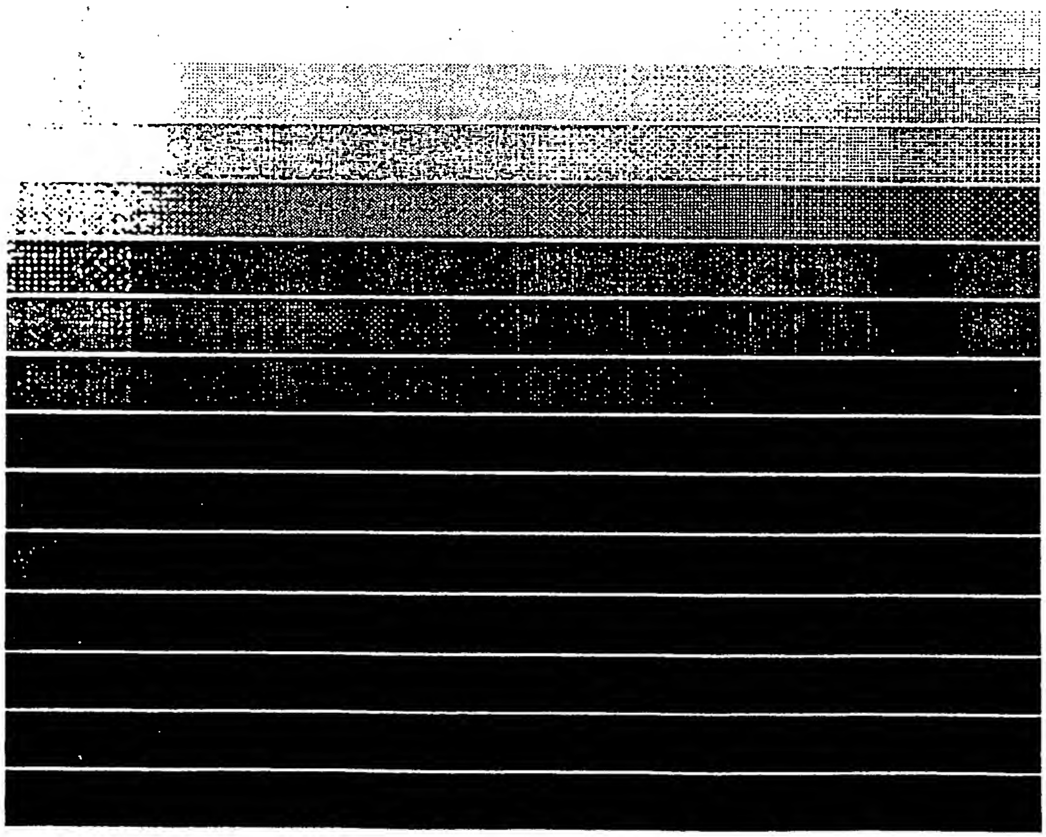


FIG. 16

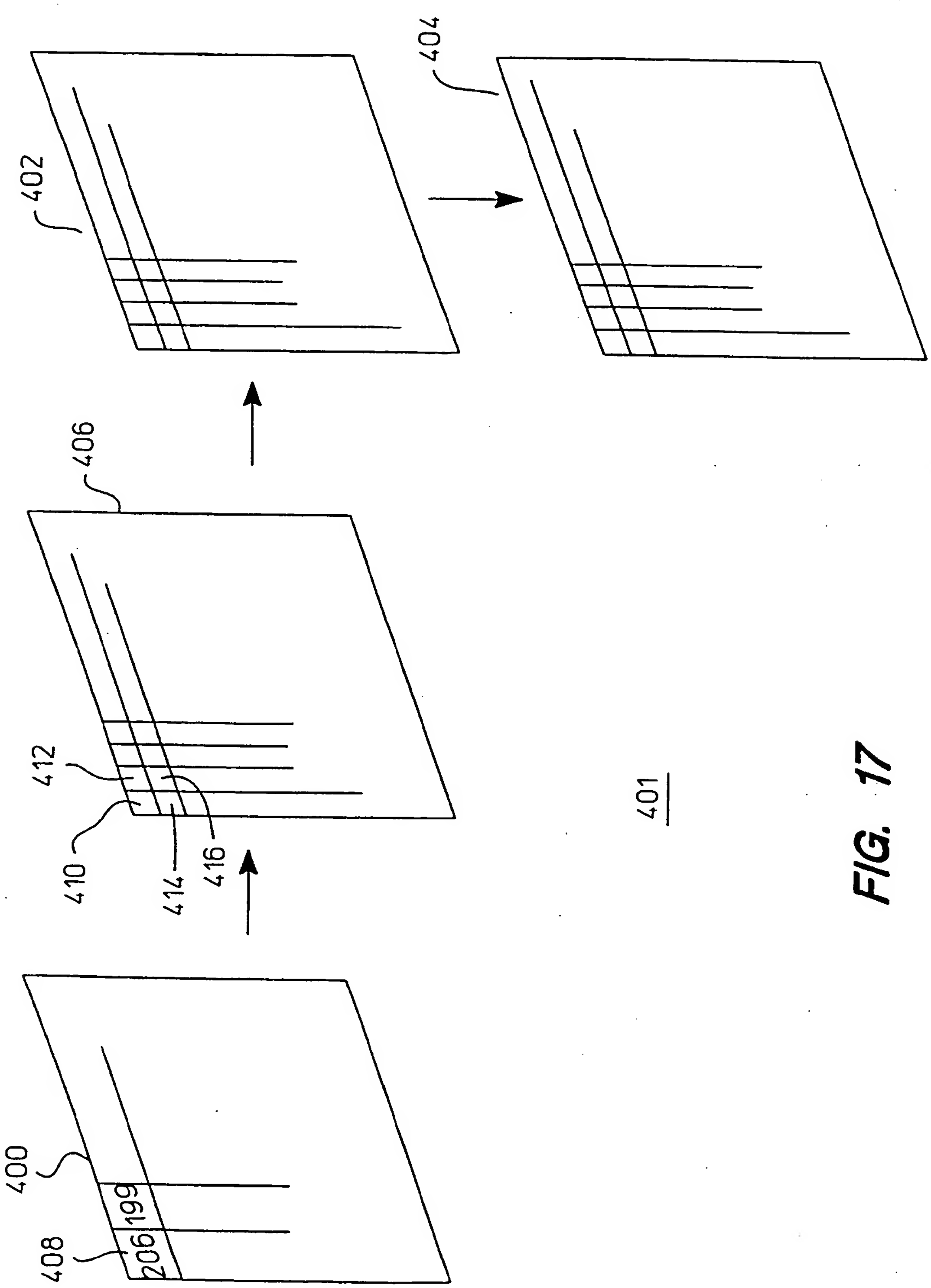


FIG. 17

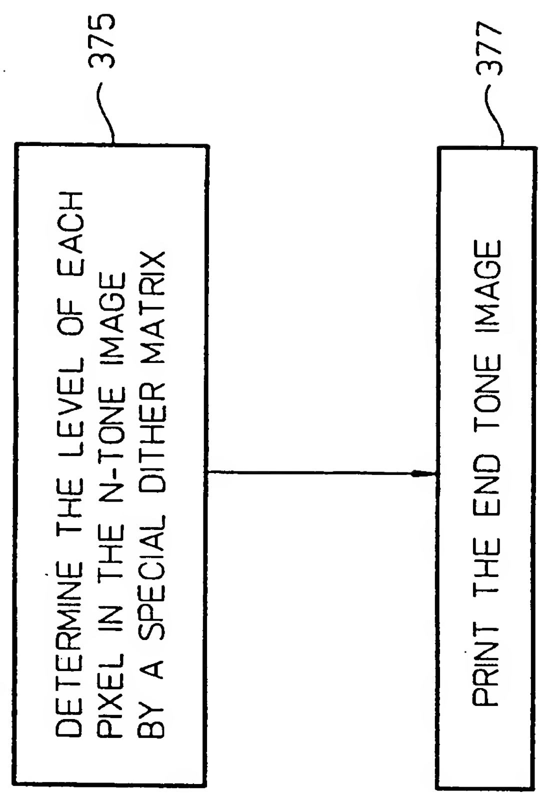

375
DETERMINE THE LEVEL OF EACH PIXEL IN THE N-TONE IMAGE BY A SPECIAL DITHER MATRIX
377
PRINT THE END TONE IMAGE

FIG. 18

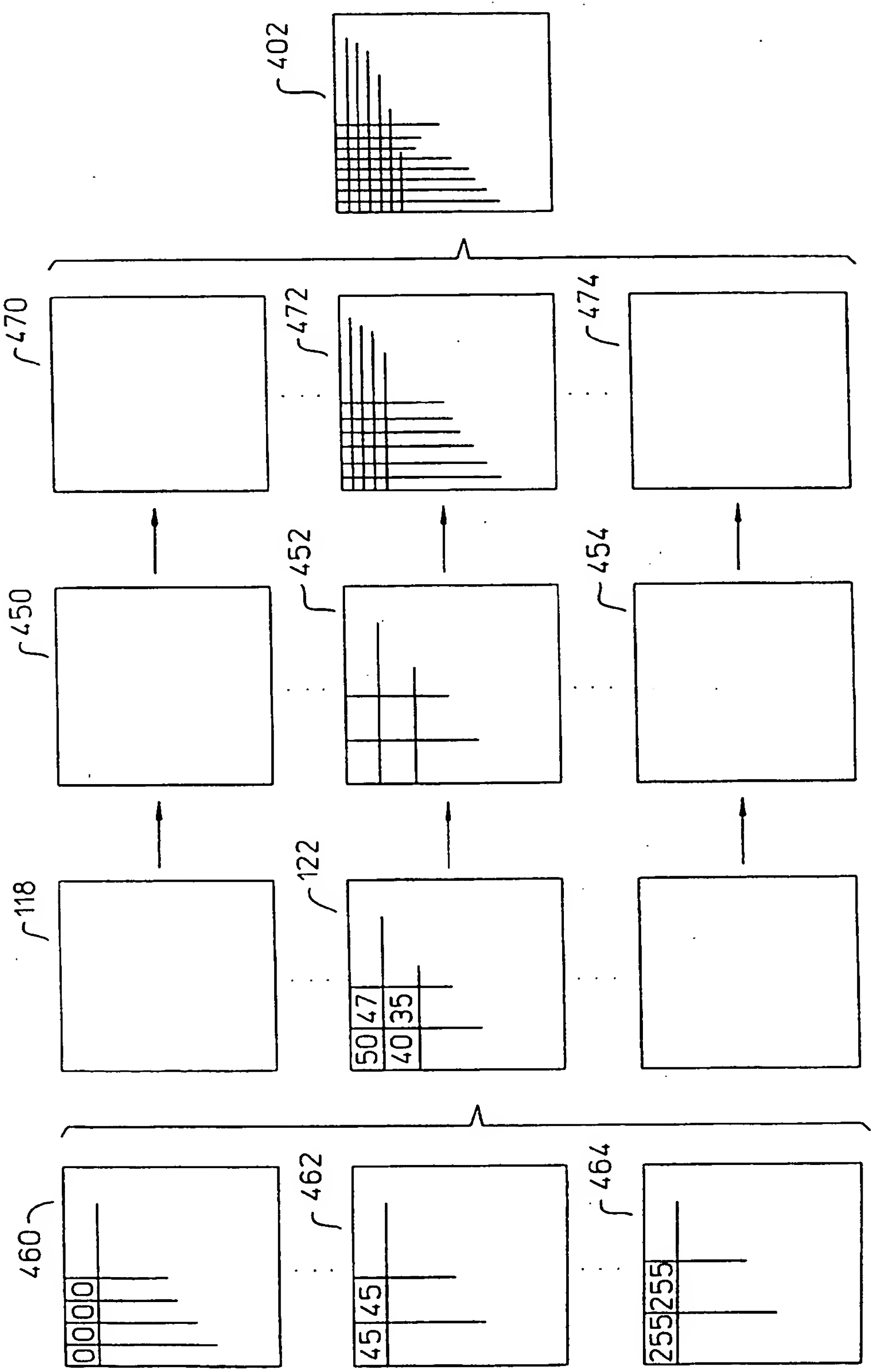

402
470
472
474
450
452
454
118
122
50 47
40 35
460
462
464
0 0 0 0
45 45 45
255 255 255

FIG. 19

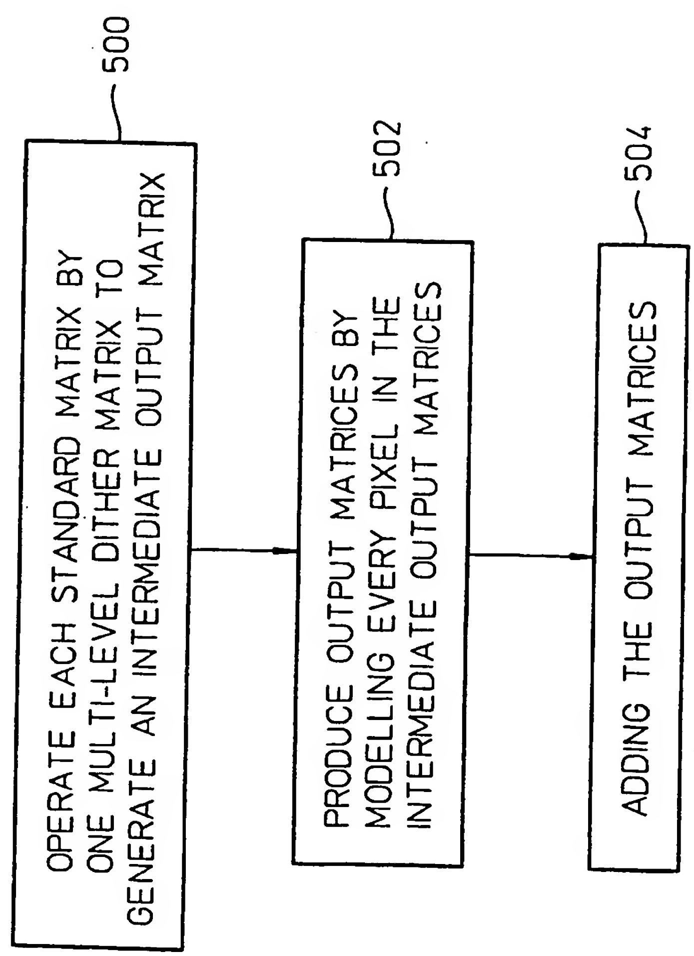

500
OPERATE EACH STANDARD MATRIX BY ONE MULTI-LEVEL DITHER MATRIX TO GENERATE AN INTERMEDIATE OUTPUT MATRIX
502
PRODUCE OUTPUT MATRICES BY MODELLING EVERY PIXEL IN THE INTERMEDIATE OUTPUT MATRICES
504
ADDING THE OUTPUT MATRICES

FIG. 20

European Patent Office

EUROPEAN SEARCH REPORT

Application Number
EP 95 30 0986

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int.Cl.6)
X Y	DE-A-35 25 011 (CANON K. K.) * the whole document *	1-4,6 5,7-10	H04N1/40
Y	FR-A-2 007 849 (DR.-ING. RUDOLF HELL) * the whole document *	5	
Y	GB-A-2 174 265 (CANON K. K.) * page 3, line 11 - line 47 * * page 4, line 4 - line 29 * * page 5, line 33 - line 55 *	7-10	
Y	US-A-5 111 310 (K. J. PARKER ET AL.) * column 8, line 17 - line 48 *	8,9	
A	EP-A-0 382 580 (CANON K. K.)		

TECHNICAL FIELDS SEARCHED (Int.Cl.6)

H04N

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
THE HAGUE	16 May 1995	De Roeck, A

CATEGORY OF CITED DOCUMENTS

X : particularly relevant if taken alone
Y : particularly relevant if combined with another document of the same category
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P : intermediate document

T : theory or principle underlying the invention
E : earlier patent document, but published on, or after the filing date
D : document cited in the application
L : document cited for other reasons

& : member of the same patent family, corresponding document